Received: 4 May 2023 | Accepted: 19 May 2023

DOI: 10.1002/ecs2.4598

ECOSPHERE
AN ESA OPEN ACCESS JOURNAL

ARTICLE
Climate Ecology

Opposite response of N_2O emissions in different seasons to warming and precipitation addition on a temperate steppe

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Funding information
Central Public-interest Scientific Institution Basal Research Fund for Chinese Academy of Tropical Agricultural Sciences, Grant/Award Number: BSRF202210; Fundamental Research Funds for the Inner Mongolia Normal University, Grant/Award Number: 2022JBQN095; National Natural Science Foundation of China, Grant/Award Number: 32260278; Natural Science Foundation of Inner Mongolia, Grant/Award Number: 2021BS03024; Youth innovation Program of Chinese Academy of Agricultural Sciences, Grant/Award Number: Y2023QC08

Handling Editor: Kristofer D. Johnson

Abstract

Climate change is an important issue that affects both global warming and precipitation, and the main cause is increased N_2O emissions. Temperature and moisture are key factors in grassland ecosystem's response to climate change, and they can affect N_2O fluxes. To clarify the impacts of warming and precipitation changes on N_2O fluxes, an experiment was conducted in a semi-arid steppe in Inner Mongolia, China over a nine-year period (2011–2019). Plant productivity and soil nutrient dynamics were examined concurrently from 2017 to 2019, and N_2O fluxes were monitored in response to different treatment conditions: control (C), warming (W), precipitation addition (P), and warming and precipitation addition (WP). The results showed that N_2O emissions in the growing season were higher than those in the nongrowing season. Warming and precipitation addition had no significant effect on N_2O fluxes compared with ambient conditions. Compared with P treatment, warming increased N_2O flux in nongrowing season and decreased it in growing season. N_2O flux was positively correlated with soil temperature and moisture ($p < 0.05$). Warming had a significant positive effect on soil NH_4^+-N, whereas additional precipitation had a large positive effect on soil total nitrogen and soil nitrate nitrogen. With the WP treatment, soil microbial biomass nitrogen (MBN) and soil microbial biomass carbon (MBC) increased by 53.8% and 41.9%, respectively. The decrease in N_2O emissions during the growing season in the W treatment compared with the P treatment may be largely attributed to the greater dominance of *Leymus chinensis*. The results highlight that changes in species dominance play an important role in regulating N_2O emissions, and that the N_2O fluxes in the nongrowing season account for a large proportion of the changes in N_2O fluxes. Therefore, The warming effects on N_2O emissions during nongrowing seasons should be further investigated.

Zhiqiang Wan and Rui Gu contributed equally to this study.

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KEYWORDS
climate change, growing season, N_2O flux, nongrowing season, precipitation, temperate steppe, warming

INTRODUCTION

Climate change is an important global issue (Landman, 2007) caused by the high levels of greenhouse gas emissions (CO_2, CH_4, and N_2O) that result from anthropogenic activities. Although the emission rates of N_2O are relatively low, its warming potential is high, as it has a 150-year atmospheric residence duration and contributes to 7% of the present anthropogenic greenhouse effect (Peng et al., 2011). Owing to anthropogenic perturbations of the global N cycle, the atmospheric concentration of N_2O has increased dramatically (Wolf et al., 2010), from approximately 270 ppb at the start of the industrial period to 319 ppb in 2005, and it continues to rise by 0.2%–0.3% per year. Global climate change has significantly influenced ecosystems and human society (IPCC, 2022). Grassland ecosystems are a significant part of the terrestrial ecosystem, accounting for 24% of the land area, and the fluxes in N_2O have feedback effects on climate change (Nakano & Shinoda, 2010). The steppe in Inner Mongolia, located in eastern Eurasia, is an important ecosystem barrier in northern China and is sensitive to climate change. Therefore, an accurate understanding of the effects of climate change on N_2O fluxes in this ecosystem will be required to understand and manage future climate change.

Many studies have shown that changes in temperature and precipitation affect the N_2O fluxes in terrestrial ecosystems (Dijkstra et al., 2012; Strong & Fillery, 2002). Furthermore, a substantial positive linear correlation exists between precipitation and N_2O average emission fluxes (Yue et al., 2016); however, N_2O emissions also increase with temperature (Mosier & Parton, 2008). This phenomenon is caused by restrictive differences in environmental factors in different ecosystems. Warming has no effect on the N_2O fluxes in semiarid regions as the positive effect of the soil temperature increase on N_2O fluxes is offset by the negative effects of the soil moisture decrease caused by warming (Bijoor et al., 2008). Although soil moisture and temperature explain most of the variations in N_2O fluxes, plant soil N and C pools respond differently to climate change and may also be important factors affecting N_2O fluxes (Kuzyakov & Gavrichkova, 2010; Phillips et al., 2012; Potthast et al., 2010; Shaver et al., 2000).

Although N_2O emissions originating from grassland ecosystems have been examined globally (Schulze et al., 2010; Vilain et al., 2010), most measurements have been recorded during the growing season and in short-term studies (Dijkstra et al., 2013; Jiang et al., 2010; Li et al., 2015; Wei et al., 2014; Zhu et al., 2015). Grasslands have not been widely investigated with regard to their N_2O emissions throughout the year, including the winter and spring melt periods (Soussana et al., 2007; Wolf et al., 2010).

Long-term and continuous warming and precipitation addition experiments in Inner Mongolia, China, began in 2011, based on climate change trends in typical steppes. The N_2O flux was observed from 2017 to 2019 during the growing and nongrowing seasons. The aim was to clarify (1) the effects of warming and precipitation and (2) the main factors affecting the N_2O fluxes. We hypothesized that (1) warming may limit N_2O emissions and affect the proportion of N_2O fluxes in the growing and nongrowing seasons, and (2) that abiotic factors such as temperature, soil moisture, soil carbon, and nitrogen would be the main factors affecting N_2O fluxes.

MATERIALS AND METHODS

Site and experimental design

A plot situated in the Grassland Ecological Research Station of Inner Mongolia University in Xilinhot, Inner Mongolia, China (44°09′ N, 116°29′ E, 1102 m above sea level) was the site of this investigation. The average annual precipitation at the site during the experimental period was approximately 271 mm, with May to September accounting for 87% of the total. The average annual temperature was 2.6°C, with July being the hottest month with a mean of 21.4°C and January being the coldest with a mean of −19.0°C (data were acquired from the China Meteorological Data Sharing Service System of the China Meteorological Administration). Furthermore, the soil was chestnut and it was dominated by *Stipa krylovii* and *Leymus chinensis*.

The experiment began in July 2011, and open-top chambers (OTCs; transparent plastic columns, 0.40 m in height, 1.20-m base diameter, and 0.70-m top diameter) were used for warming. Fans were installed inside to control the temperature increase. The precipitation addition range was 20% of the average monthly precipitation from 1961 to 2010, and precipitation additions were performed twice each month of the growing season. Water (48 mm;

20% of the mean precipitation during the growing season from 1961 to 2010) was added to each plot in 5, 9, 16, 13, and 5 mm doses in May, June, July, August, and September, respectively. Due to the differences between the top area and the bottom area of the OTCs (0.75 m^2), 0.75 times the precipitation in the OTCs was added for a given month to eliminate the rain sheltering effects. The mean soil temperature was significantly increased by the OTCs, soil temperature increased by 10.9% and soil moisture decreased by 17.5% under warming compared with control (Appendix S1: Table S1). The addition of precipitation significantly increased soil moisture, soil temperature decreased by 6.6% and soil moisture increased by 14.4% under precipitation addition compared with control. And for the OTCs, precipitation addition alleviated the decrease in soil moisture caused by warming (Appendix S1: Table S1). Four treatments, control (C), warming (W), warming plus precipitation addition (WP), and precipitation addition (P), were established with four replicates for each treatment, totaling 16 experimental plots. Greenhouse gases were then collected and measured from 2017 to 2019.

Soil temperature and soil moisture

Soil moisture and temperature at a depth of 10 cm were recorded using a data collector at 15-min intervals (Ecotek Inc., Beijing, China; moisture probe model: EC-5, Ecotek Inc.).

Community characteristics and soil carbon and nitrogen investigation

A quadrat method (0.5 × 0.5 m^2) was used to measure the density and height of all species in August from 2013 to 2021. Density (number of individuals per square meter) was calculated by counting the number of members of each species in the quadrant. Five individuals per species were selected to calculate the mean height. The relative height (or relative density) was calculated as the proportion of species height (or density) to the sum of all species heights (or densities). The important value (IV) was determined for each species, which measures species dominance based on the average relative density and relative height. The biomass of each species was then determined using a nondestructive method. Species number, density, and height outside the experimental plots were measured using the same method as for within the experimental plots at 100 sampling quadrats each August from 2013 to 2015. The plants were then all clipped and the biomass of each species was measured after drying. To investigate the relationships among biomass, plant height, and plant density, a linear regression model was built. These models were then used to estimate biomass in the experimental plots (Appendix S1: Table S2). Species diversity and dominance were calculated, and the results are shown in Appendix S1: Tables S3 and S4.

One soil sample was taken (0–15 cm deep) from each plot using an auger (5 cm in diameter), which was then sieved (2 mm). Roots were extracted from the soil specimens using a sieve to measure root biomass. Wet oxidation with $K_2Cr_2O_7$ and the semi-micro Kjeldahl technique were used to measure total organic carbon (TOC) and total nitrogen (TN), respectively (Peng et al., 2011). Microbial biomass nitrogen (MBN) and carbon (MBC) were measured using a chloroform-fumigation extraction method (Dannenmann et al., 2006). An autoanalyzer (Auto Analyzer 3, Bran Luebbe, Germany) was used to estimate the soil NH_4^+-N and NO_3^--N contents using a 2 mol/L KCL extract (Wei et al., 2014). The dissolved organic carbon (DOC) and dissolved organic nitrogen (DON) were then determined using a multi N/C 3000 DOC tester (Jena, Germany).

N_2O flux measurement

A closed, static, and opaque container with inner dimensions of 40 × 30 cm (diameter × height) was used to test the N_2O fluxes. To reduce the heating influence of solar radiation during the course of sampling, thermal insulation foam was applied to the exterior of each chamber. To avoid leakage during gas sampling, the chamber was mounted on a collar with a groove in the individual plots, placed in the soil at a depth of 5 cm, and sealed with water. A 30 mL plastic syringe was then used to obtain gas samples from the chambers 0, 10, 20, and 30 min after closing and each was immediately transferred into a pre-evacuated 10 mL air bottle. N_2O fluxes were measured 31 times in all plots from 2017 to 2019, once each during the growing season (May–September) and nongrowing season (October–April). The gas sampling was obtained between 9:00 and 11:00. Gas chromatography was performed to determine the levels of N_2O in the gas samples (Agilent 4890D; Agilent Technologies, Wilmington, DE, USA). The oven temperature was set to 60°C, and the outside diameter of the column was 1/8 with a 2.74 m Poropak Q (80/100 mesh). A Micro Electronic Capture Detector (ECD) was used, and the operating temperature was maintained at 330°C (Peng et al., 2011).

$$F = \rho \times h \times \frac{\Delta C}{\Delta t} \times \frac{273.15}{273.15 + T} \quad (1)$$

where ρ refers to the N_2O gas density (in micrograms per cubic meter), F denotes the N_2O flux (in micrograms per square meter per hour), h indicates the height of the chamber (in meters), $\Delta C/\Delta t$ corresponds to the slope of the linear regression for gas concentration gradient over time ($m^3\ m^{-3}\ h^{-1}$), and T refers to the mean air temperature during sampling (in degrees Celsius).

Data analysis method

Using Shapiro–Wilk and Bartlett's tests, the normality of distributions and homogeneity of variance were examined before performing any further analysis. No data transformation was required as all parameters satisfied these assumptions. The single and combined effects of warming and additional precipitation on soil carbon, soil nitrogen, and N_2O fluxes were examined using linear mixed-effects models. The block was established as a random effect, whereas the treatments were fixed effects. To compare variations between treatments, a post hoc test utilizing least significant difference (LSD) techniques was performed. To investigate the correlations between the N_2O flux and effect components, linear regression techniques were used.

RESULTS

Effects of warming and precipitation additions on the N_2O flux

The effects due to changes in temperature and precipitation on the N_2O flux were weak, with no significant differences overall for the entire year between the different treatments (Figure 1).

The ratio of the N_2O flux in the growing and nongrowing seasons when compared with the annual measurements, however, was considerably altered by warming and precipitation. Warming reduced the proportion of the N_2O flux that occurred in the growing season when compared with the annual level and increased the proportion in the nongrowing season when compared with the precipitation addition. In 2018, the N_2O flux in the growing season accounted for 63.3% and 60.0% of the total for the entire year with the W and WP treatments, respectively, and 72.0% with the P treatment; while in the nongrowing season it accounted for 36.7% and 40% of the total for the entire year with the W and WP, respectively, and 28.0% with the P treatment. The ratio of the N_2O flux in the growing season to that in the nongrowing season significantly increased under P compared with the

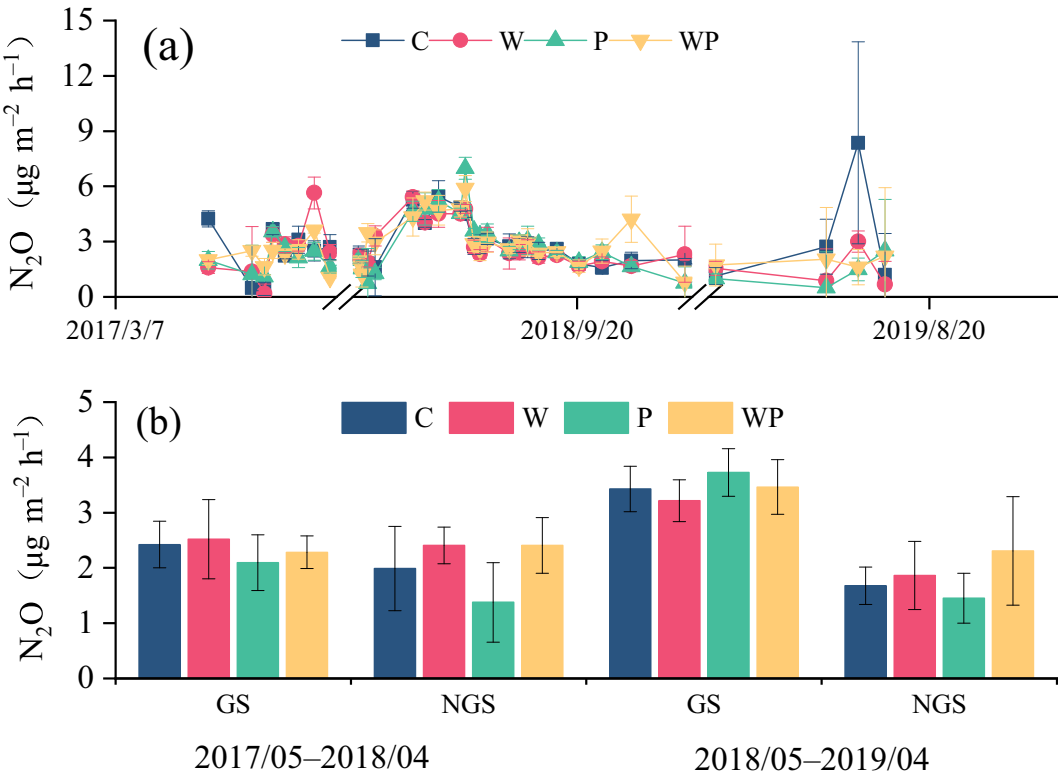


FIGURE 1 Effects of temperature and precipitation additions on the N_2O flux in typical steppe in Inner Mongolia, China. C, control, no warming and no precipitation addition; GS, growing season; NGS, nongrowing season; P, precipitation addition; W, warming; WP, warming plus precipitation addition. *$p < 0.05$. The data are the means ± SD for the N_2O fluxes under different treatments.

warming. In 2018, the ratio was 1.73 and 1.50 under W and WP, respectively, while it was 2.56 under P (Figure 2). This shows that while the precipitation addition boosted N_2O emissions in the growing season and inhibited emissions in the nongrowing season, the warming inhibited N_2O emissions in the growing season and promoted the same in the nongrowing season. This may be because warming during the growing season intensified the metabolism of soil microorganisms owing to the warming and soil moisture shortage. Warming mitigated the impact of low temperatures on soil microorganisms and enzyme activity during the nongrowing season. Precipitation additions in the growing season could alleviate the adverse environment due to water shortages in the region, while higher soil water content in the nongrowing season could increase the air-passing capacity in the soil that occurs with low temperatures. This shows that the N_2O flux in the nongrowing season will increase due to warming in the future, and will thus require further investigation.

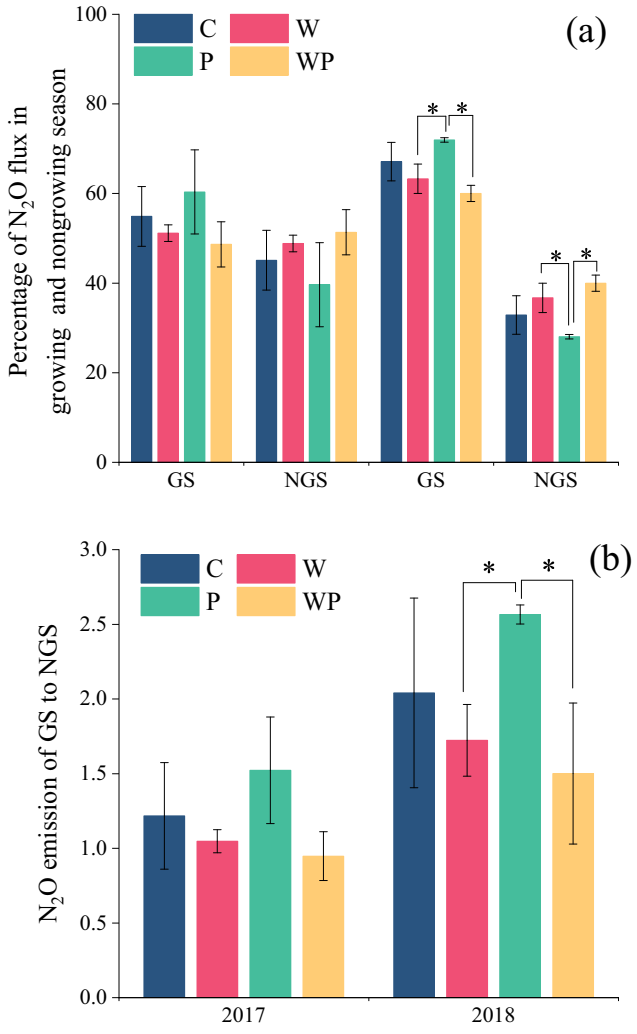


FIGURE 2 N_2O fluxes during the growing season and nongrowing season in the whole year and N_2O emissions from the growing season (GS) to non-growing season (NGS). C, control, no warming and no precipitation addition; P, precipitation addition; W, warming; WP, warming plus precipitation addition. *$p < 0.05$. The data are the means ± SD for the N_2O fluxes in different seasons under different treatments.

Influence of precipitation additions and warming on the soil carbon and nitrogen content

Total carbon (TC) and DOC were not significantly different among the different treatments, and in 2017, there were no discernible differences in TN among the treatments. In 2018, however, the influx of precipitation caused the TN to increase significantly ($p < 0.05$). In 2017, there was no discernible variation in the soil NH_4^+-N concentrations. In 2018, warming significantly increased the soil NH_4^+-N content, 2.64 (in milligrams per kilogram) higher than the C, and the precipitation addition increased the NO_3^--N content; however, warming plus the precipitation addition decreased the soil NO_3^--N more than the precipitation addition alone. Soil inorganic nitrogen exchange was dominated by NH_4^+-N under warming conditions and NO_3^--N under precipitation conditions. The NO_3^--N content under precipitation was higher than that in the other treatments, which may be related to enhanced plant respiration and microbial activity. Warming plus precipitation increased MBN and DON in 2018, indicating that simultaneous changes in temperature and moisture promoted the release of MBN in the soil (Figure 3).

Effects of the warming and precipitation addition on the N_2O flux

The relationships among the N_2O flux, soil moisture, and temperature were positive ($p < 0.05$). The N_2O emissions were stimulated by warming and increased precipitation (Figure 4). The AMO activity and N_2O flux showed a strong negative relationship (Figure 5). Soil NH_4^+-N content was significantly positively correlated with the proportion of N_2O flux in the growing season to the annual year and nongrowing season, whereas soil NO_3^--N was significantly negatively correlated with the proportion of N_2O flux in the growing season to the annual year and nongrowing season (Figure 5). The dominance of *L. chinensis* was significantly positively correlated with the N_2O flux (Figure 5). Plant growth was stagnant in the nongrowing season, but warming increased the environmental temperature and promoted microbial metabolism and nutrient cycling, thus increasing N_2O emissions.

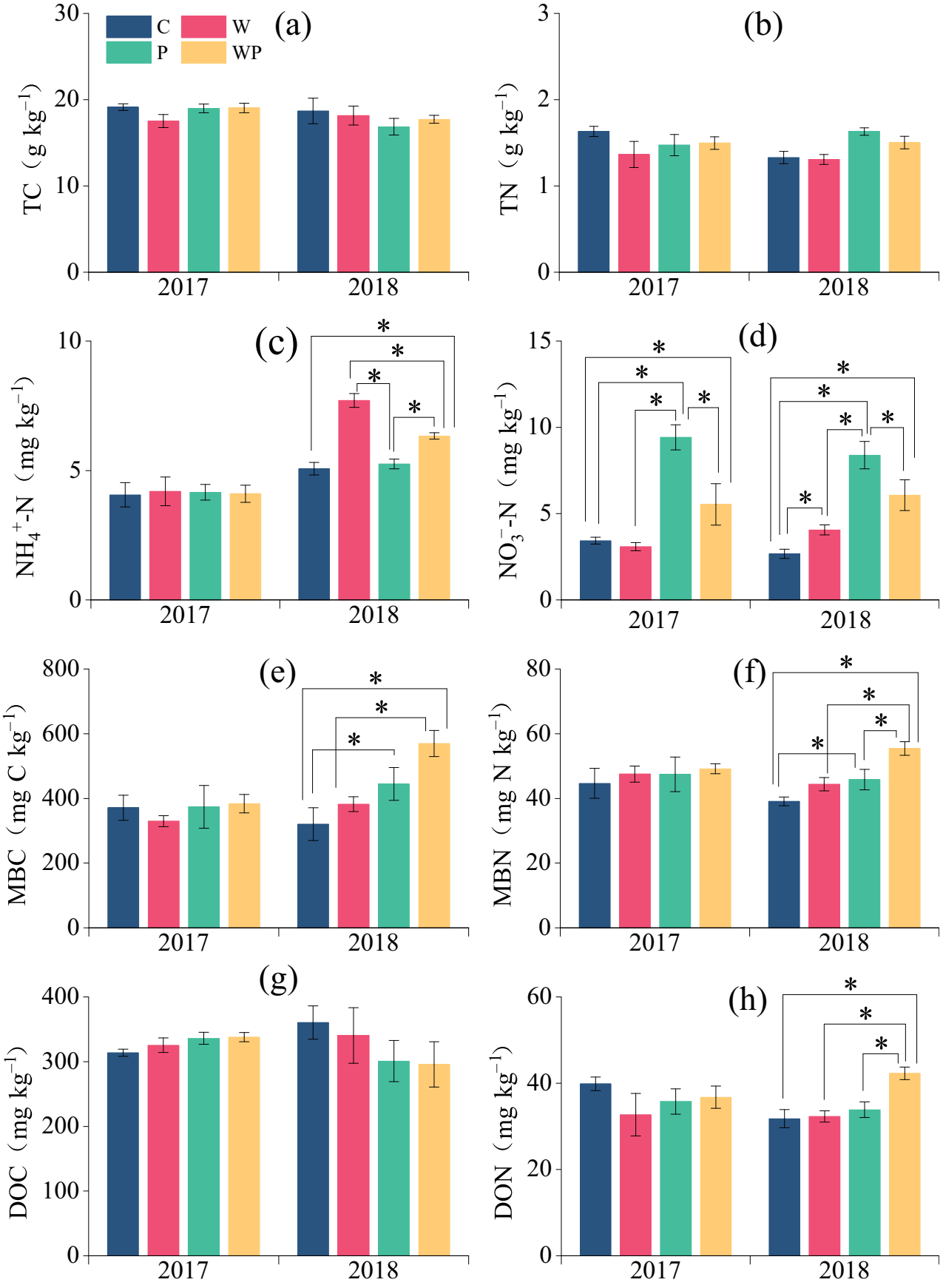


FIGURE 3 Legend on next page.

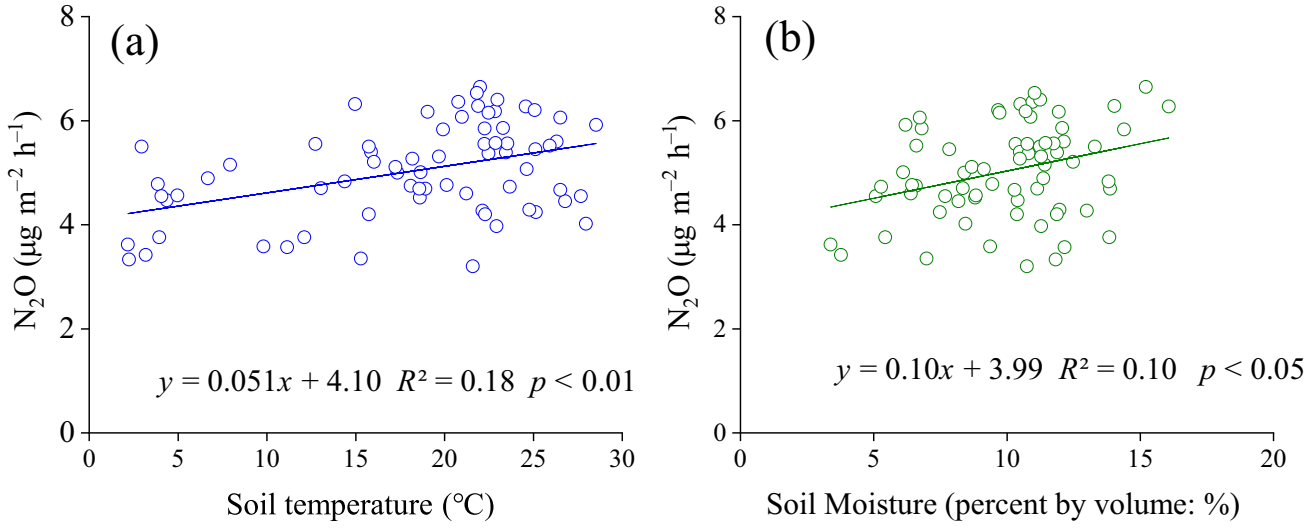


FIGURE 4 Correlation of the N_2O fluxes with soil temperature and moisture.

DISCUSSION

Impact of the precipitation additions and warming on community productivity, soil carbon, and soil nitrogen

Warming considerably increases soil temperature, as well as other elements that affect plant growth, such as soil nitrogen and carbon (Huang et al., 2015; Sheik et al., 2011). However, warming also reduces soil surface water, and this indirectly leads to drought, which in turn leads to a decline in plant productivity in arid and semiarid areas (McDowell et al., 2011; Zhao & Running, 2010). Studies have also shown that warming can increase community productivity, especially in low-temperature areas (Hua et al., 2008; Molau, 2010). In contrast, the addition of precipitation significantly increases the aboveground and underground biomass in arid areas (Bai et al., 2010), and the responses of different dominant species to combined temperature and precipitation changes are different.

Long-term warming can decrease soil carbon storage. The grassland carbon pool has a negative feedback effect on warming, and the nitrogen pool has a positive feedback effect on precipitation additions; as warming promoted an increase in unstable soil carbon content, while inhibiting an increase in stable soil carbon (He et al., 2012). Water can drive the carbon cycle and ultimately determine carbon storage in grassland soils in arid areas (Liu et al., 2009). The results of this study showed that there was no discernible difference in soil surface TC among the different treatments. According to studies, plant community composition, soil temperature, and soil moisture all have an impact on activated carbon (Gregorich et al., 2006). Carbon harvesting and soil carbon decomposition in terrestrial ecosystems are regulated by stable stoichiometry (Taylor & Townsend, 2010). The effects of warming on nitrogen loss were found to be far less than those on carbon loss, indicating that most of the nitrogen was released through the reuse and decomposition of plants and microorganisms (He et al., 2012). The significant increase in TN with precipitation additions in this study may be related to improved water conditions, which promote the decomposition rate of vegetation and the utilization rate of microbes.

MBC and MBN are highly sensitive to changes in the soil environment and represent unstable soil organic matter (Rui et al., 2011). Environmental factors have significant effects on soil MBC and MBN, and warming in particular was found to have a negative effect, which led to reductions in the MBC and MBN. In contrast, precipitation additions had a positive effect on MBC and MBN (Liu et al., 2009; Zhou et al., 2013) as the soil substrate levels were increased due to the aboveground productivity (Niu et al., 2008; Yang et al., 2011). Warming did not have a considerable influence on NH_4^+-N or NO_3^--N.

FIGURE 3 Effects of warming and precipitation on soil carbon and nitrogen. C, control, no warming, and no precipitation addition; DOC, dissolved organic carbon; DON, dissolved organic nitrogen; MBC, microbial biomass carbon; MBN, microbial biomass nitrogen; P, precipitation addition; TC, total carbon; TN, total nitrogen; W, warming; WP, warming plus precipitation addition. *$p < 0.05$. The data are the means ± SD for the soil carbon and soil nitrogen under different treatments.

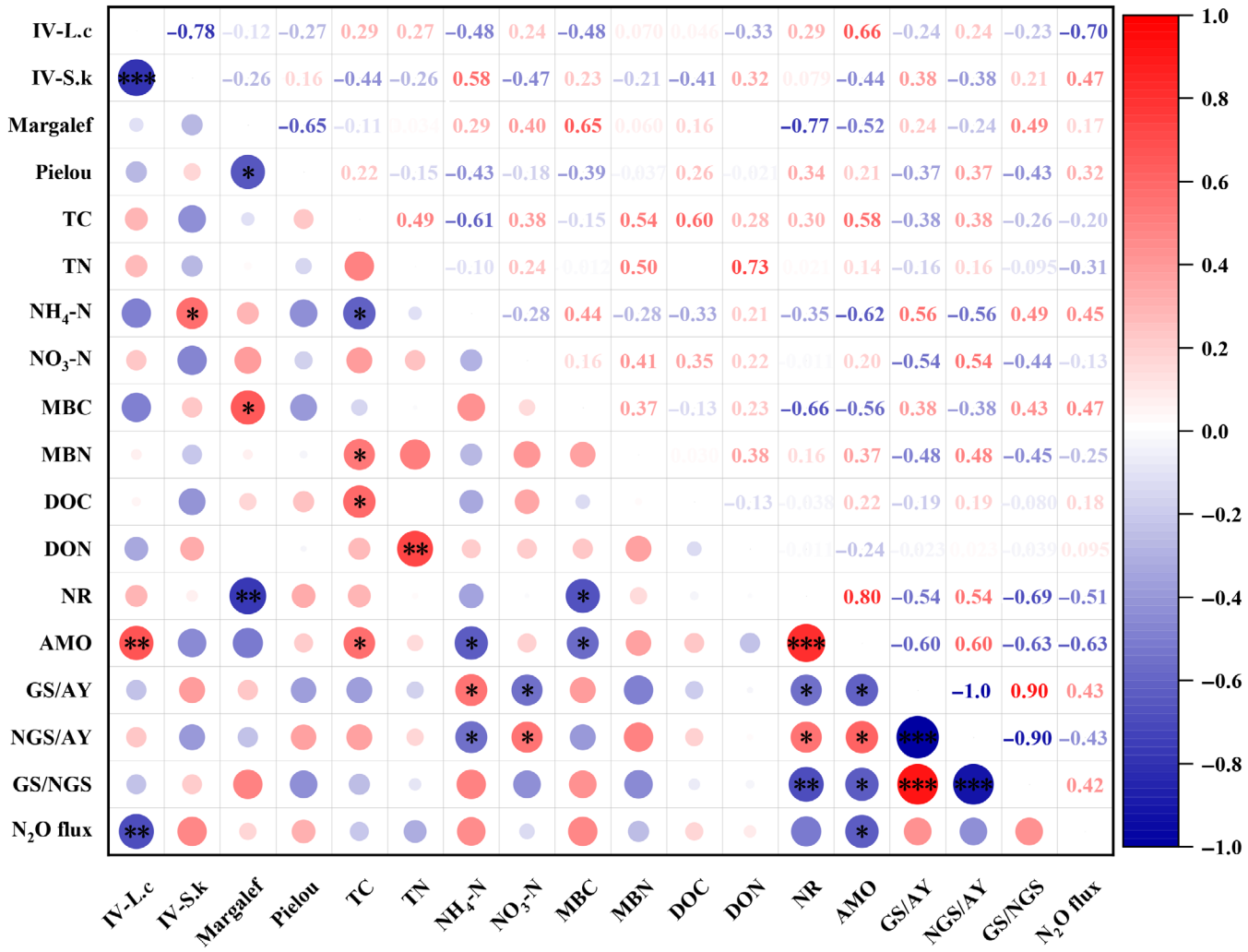


FIGURE 5 Correlation heat map for soil carbon and nitrogen, community structure, and N_2O flux. AMO, ammonia monooxygenase; DOC, dissolved organic carbon; DON, dissolved organic nitrogen; GS/AY, proportion of N_2O flux in the growing season compared with the year overall; GS/NGS, ratio of the N_2O flux in the growing season compared with that in the nongrowing season; IV-L.c, dominance of *L. chinesis*; IV-S.k, dominance of *S. krylovii*; MBC, microbial biomass carbon; MBN, microbial biomass nitrogen; NGS/AY, proportion of N_2O flux in the nongrowing season compared with the year overall; NR, nitrate reductase; TC, total carbon; TN, total nitrogen. $^*p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$.

The addition of precipitation significantly reduced NH_4^+-N and caused an increase in NO_3^--N (Staelens et al., 2012; Zhou et al., 2013). In this study, warming significantly increased NH_4^+-N and precipitation additions significantly increased NO_3^--N, while warming with precipitation additions significantly increased both NH_4^+-N and NO_3^--N.

Impacts of warming and precipitation additions on N_2O fluxes in different seasons

Grassland ecosystems are also sources of N_2O (Wang et al., 2005). Temperature has no substantial influence (Bijoor et al., 2008; Zou et al., 2018), a positive correlation (Dobbie & Smith, 2010), or a significant negative correlation (Dijkstra et al., 2013) with N_2O emissions. Soil temperature and soil moisture have been shown to have a significant positive correlation with the N_2O flux in semiarid areas (Wang et al., 2005), and this was consistent with our results. Precipitation additions promoted N_2O emissions, which may have been because soil permeability was reduced, creating an anaerobic environment and promoting denitrification to discharge N_2O under precipitation addition conditions (Xu et al., 2012). A study on a typical steppe showed that the changes in soil surface temperature can explain 85.9% of the N_2O flux change in the control treatment, while it can explain 88.0% of the N_2O flux change with the precipitation addition

treatment (Liu et al., 2014). The N_2O emissions varied significantly throughout the year in the grassland ecosystems. According to some studies, N_2O fluxes are higher throughout the growing season and lower during the winter and spring melt periods (Peng et al., 2011). The findings demonstrated that the N_2O flux in the growing and nongrowing seasons was not significantly different under the same environmental conditions, but the warming and precipitation additions did have an effect. Warming decreased the N_2O flux in the growing season but increased it in the nongrowing season. A global meta-analysis indicated a strong positive relationship between the effect size of N_2O emissions and soil moisture (Li et al., 2020). Furthermore, N_2O has been positively correlated with soil moisture within a certain range (Bijoor et al., 2008). During the growing season, soil moisture has been found to be a key factor affecting the ecosystem, and warming causes a decrease in soil moisture (Appendix S1: Table S5), which leads to decreases in the N_2O flux. In the nongrowing season, warming may maintain enzyme and microbial metabolic activities in the soil, resulting in an increase in N_2O flux. The results differed in 2017 because it was a more drought-prone year as the temperature was higher and precipitation was lower than that of 2012–2022 as a whole.

Effects of community structure, soil carbon, and nitrogen on N_2O fluxes with warming and precipitation additions

Soil temperature and moisture can explain most of the seasonal changes in N_2O fluxes; however, environmental factors have direct effects on N_2O emissions and are indirectly affected by soil nutrients and vegetation growth (Aires et al., 2008; Kuzyakov & Gavrichkova, 2010; Nakano & Shinoda, 2010; Phillips et al., 2012; Potthast et al., 2010; Sampson et al., 2007; Shaver et al., 2000; Xu & Wan, 2008). Most studies have shown that plant species affect N_2O emissions; however, the degree of their effects varies greatly (Maltais-Landry et al., 2009). Increased plant diversity can reduce N_2O emissions (Yang et al., 2019) and the net warming potential of wetland ecosystems (Du et al., 2018). There was no significant correlation between changes in vegetation growth and N_2O emissions, which may be due to the weak relationship between vegetation changes and unstable carbon input (des Roseaux et al., 2020; Dijkstra et al., 2013). However, the detrimental effects of reduced soil moisture can be partially compensated by the beneficial effects of increased biomass on N_2O emissions (Xia et al., 2009). The composition of community species plays a crucial role in N_2O emissions, as they decrease with increased species diversity (Han et al., 2017). Owing to the current lack of rigorous experimental research, the mechanisms of diversity and important species values affecting the N_2O flux remain at the theoretical assumption stage. One possible explanation is that high levels of plant diversity could enable the soil to obtain sufficient levels of mineralized nitrogen (Spehne et al., 2005), and nitrogen utilization among species in the community results in obvious differentiation, which thus improves the nitrogen utilization rate (Mckane et al., 2002).

N_2O emissions are likely related to unstable soil carbon and nitrogen pools (Zou et al., 2018). Precipitation changes the soil nitrogen dynamics, indirectly leading to increases in the N_2O emissions (Trost et al., 2013). The N_2O flux increases significantly with the availability of soil nitrogen in soils with lower N content (Carrillo et al., 2012). Warming reduced N_2O fluxes during the growing season by affecting the dominant species. Plant growth was stagnant in the nongrowing season, but warming increased the environmental temperature and promoted microbial metabolism and nutrient cycling, thus increasing N_2O emissions. The differential impacts of warming on vegetation and soil during the growing and nongrowing seasons should be further investigated.

CONCLUSION

N_2O emissions originating from a typical steppe were found to be higher during the growing season than the nongrowing season. Warming and precipitation addition had no significant effect on N_2O flux compared with the control treatment, but warming increased the proportion of N_2O in nongrowing season and decreased that in growing season compared with precipitation addition treatment. There was no significant correlation between soil carbon or nitrogen and N_2O emissions. Change in the species composition had significant effects on N_2O emissions. Specifically, the dominance of *L. chinensis* had significant negative effects on N_2O emissions. It is essential to consider both growing and nongrowing seasons and to clarify the impact of plant community structure when discussing the responses of N_2O fluxes to future climate change.

AUTHOR CONTRIBUTIONS

Hasbagan Ganjurjav and Qingzhu Gao designed the research. Zhiqiang Wan and Rui Gu performed the experiments. Zhiqiang Wan and Hasbagan Ganjurjav analyzed the data and wrote the draft. Guozheng Hu, Xiling Gu, Xuemeng Chen, Xi Chun, Haijun Zhou, and Qingzhu Gao revised the manuscript.

ACKNOWLEDGMENTS

The authors acknowledge the financial support from the National Natural Science Foundation of China (32260278), Fundamental Research Funds for the Inner Mongolia Normal University (2022JBQN095), Central Public-interest Scientific Institution Basal Research Fund (BSRF202210), Youth Innovation Program of Chinese Academy of Agricultural Sciences (Y2023QC08), and Natural Science Foundation of Inner Mongolia (2021BS03024).

CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

Data (Wan, 2023) are available from Figshare: https://doi.org/10.6084/m9.figshare.23123588.

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How to cite this article: Wan, Zhiqiang, Rui Gu, Hasbagan Ganjurjav, Guozheng Hu, Qingzhu Gao, Xuemeng Chen, Xiling Gu, Xi Chun, and Haijun Zhou. 2023. "Opposite Response of N_2O Emissions in Different Seasons to Warming and Precipitation Addition on a Temperate Steppe." *Ecosphere* 14(6): e4598. https://doi.org/10.1002/ecs2.4598